中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

Status and Perspective of the

High Intensity Heavy-Ion Accelerator Facility (HIAF)

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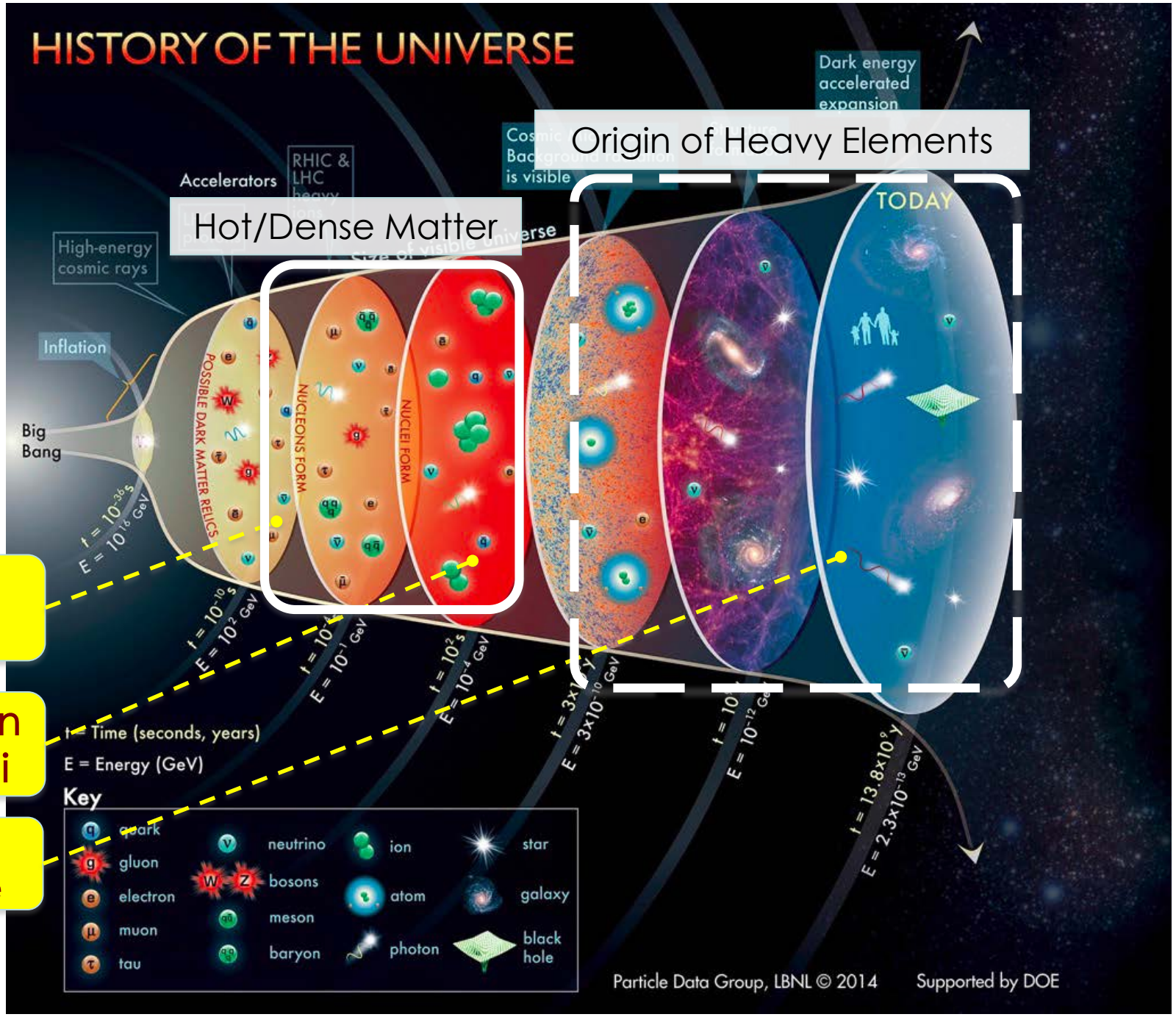
1st SYMPOSIUM ON INTERMEDIATE-ENERGY HEAVY ION COLLISONS
Tsinghua University, 2018.4.8-10

Outline

- Introduction
- HIAF and Its Physics
- Future Plan and EicC



Big-Bang

QGP

Formation of Nuclei

Today Universe

IMP Facilities History

Institute of Modern Physics (IMP)

1958

SFC

1976

SSC

1996

CSR

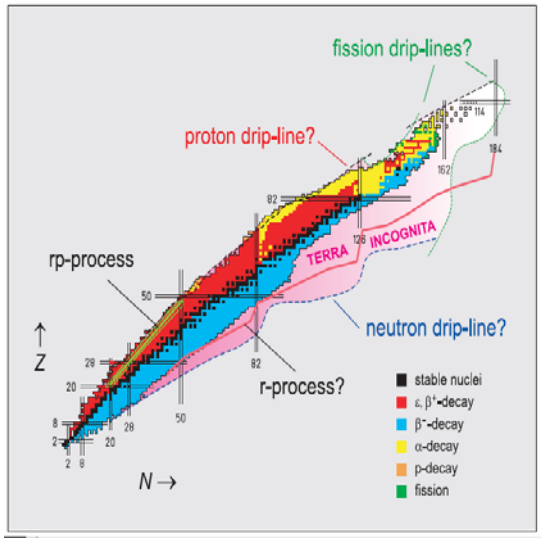
2015

HIAF

CIADS

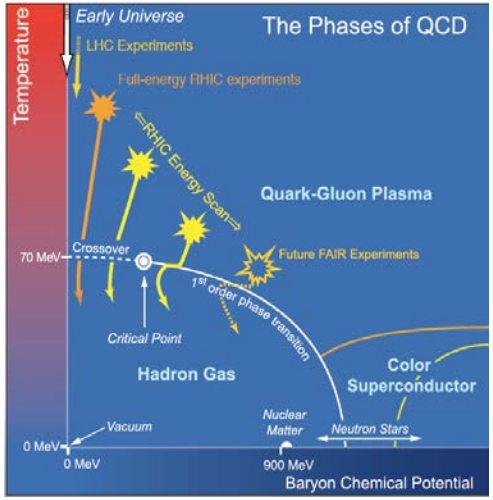
Nuclear Physics Research Plan at IMP

Nuclear Structure



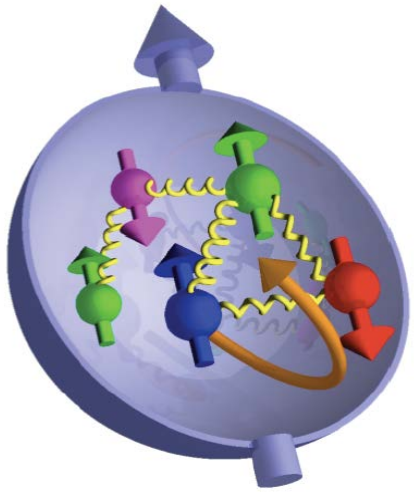
CSR

QCD Phase Structure



CEE/HIAF

Nucleon Structue

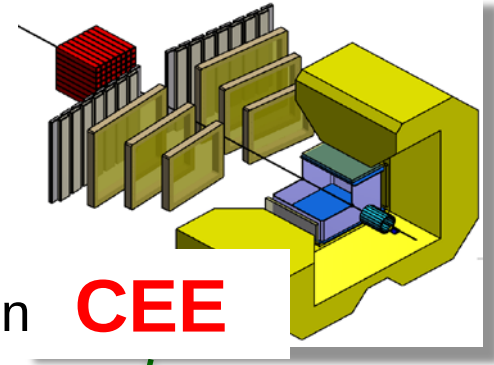


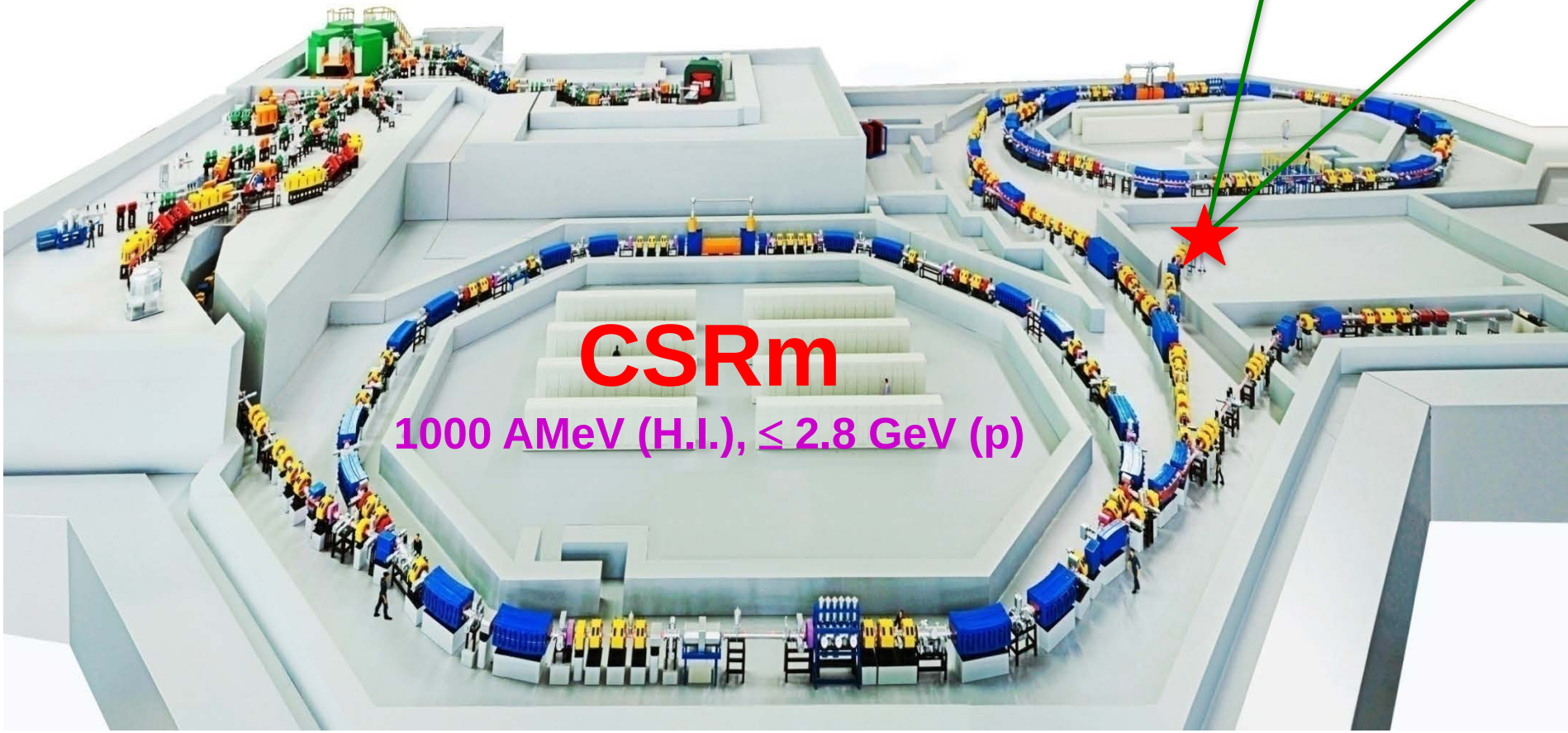
EicC

Lanzhou(HIRFL-CSR）

CEE: CSR External-target Experiment

1) Extreme high baryon density and low temperature region
2) Strong nucleonic interactions





High Intensity heavy-ion Accelerator Facility (HIAF)

- One of 16 large-scale research facilities proposed in China in order to boost basic science in 12th – 5 years plan (2011-2015)
- Approved was in December 2015. Budget: 1.5+1.1B CNY
- Now it is under technical design, will start construction in 2018
- Operation in 2024

High Intensity heavy-ion Accelerator Facility (HIAF)

Primary beam I vs: HIRFL: 10^3 – 10^4

Secondary beam I vs: HIRFL: 10^4

BRing2: Booster ring 2
Circumference: 600 m
Rigidity: 86 Tm
Beam stacking
Super-conducting

External target station

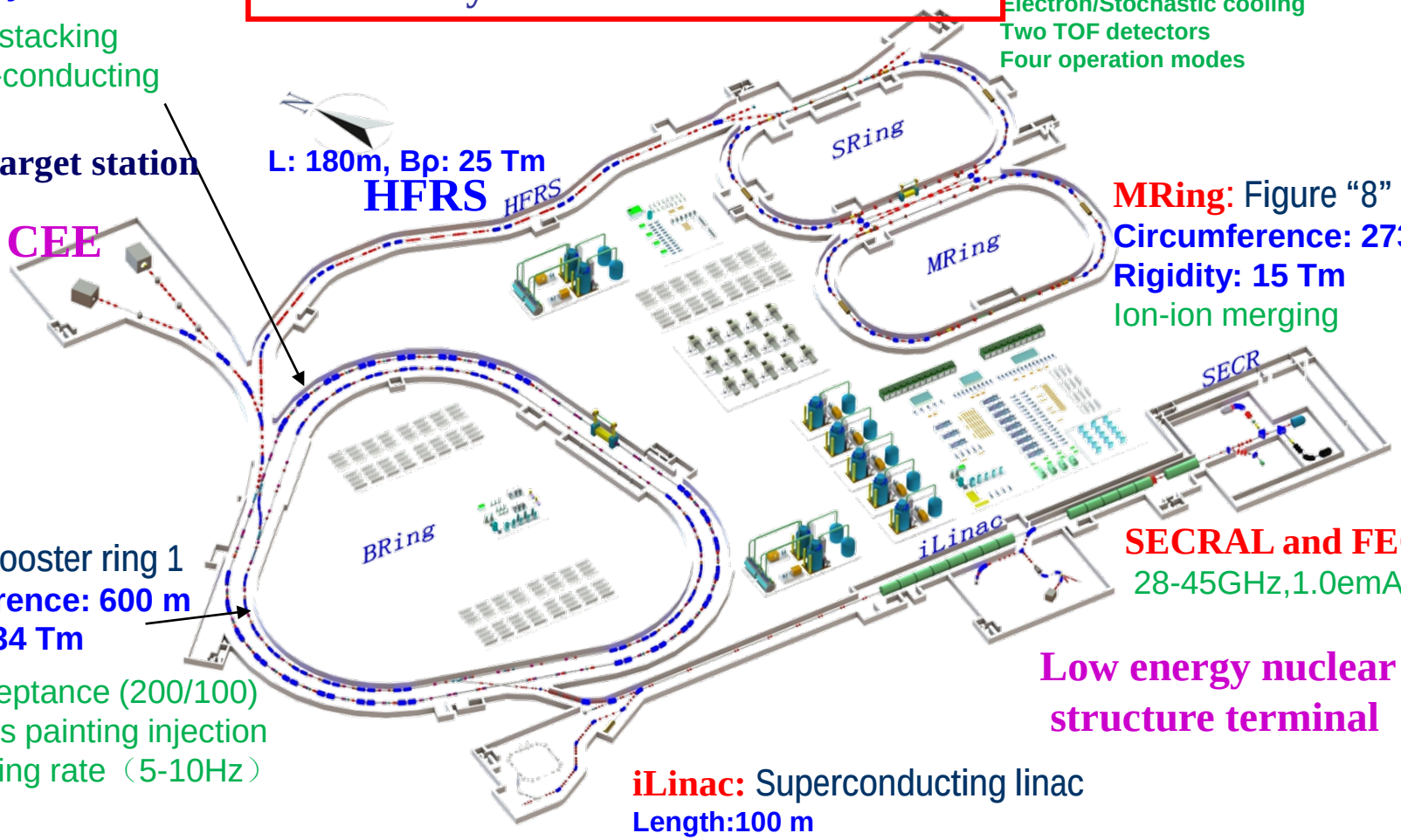
L: 180m, Bρ: 25 Tm

HFRS

CEE

SRing: Spectrometer ring
Circumference: 273m
Rigidity: 13-15 Tm
Electron/Stochastic cooling
Two TOF detectors
Four operation modes

MRing: Figure "8" ring
Circumference: 273m
Rigidity: 15 Tm
Ion-ion merging



SECRAL and FECR
28-45GHz,1.0emA(U^{35+})

Low energy nuclear structure terminal

BRing1: Booster ring 1
Circumference: 600 m
Rigidity: 34 Tm
Large acceptance (200/100)
Two planes painting injection
Fast ramping rate（5-10Hz）

iLinac: Superconducting linac
Length:100 m
Energy: 17~22 MeV/u($U^{35+\sim 46+}$)

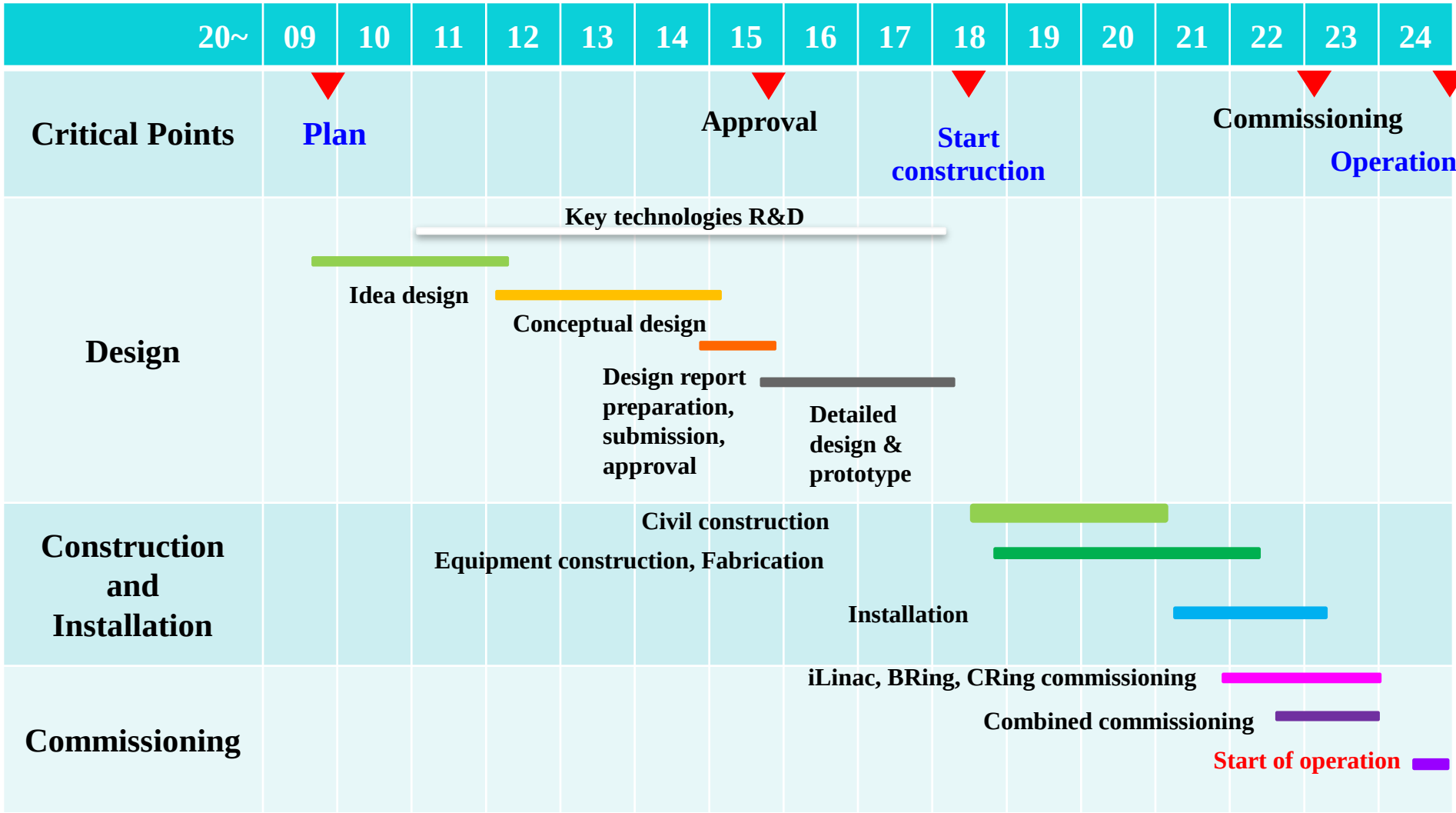
HIAF Beam Parameters

	Ions	Energy	Intensity
SECR	$^{238}U^{35+\sim 46+}$	14 keV/u	0.05-0.1 pmA
iLinac	$^{238}U^{35+\sim 46+}$	17~22 MeV/u	0.028-0.05 pmA
BRing1	$^{238}U^{35+\sim 46+}$	0.8~1.2 GeV/u	2.0×10^{11} ppp
BRing2	$^{238}U^{35+\sim 46+}$	3~4.1 GeV/u	$\sim1.0\times10^{12}$ ppp
	$^{238}U^{92+}$	3.8 GeV/u	$\sim5.0\times10^{11}$ ppp
SRing	RIBs: neutron-rich, proton-rich	0.84 GeV/u(A/q=3)	$\sim10^{9\text{-}10}$ ppp
	Fully stripped heavy ions H-like, He-like heavy ions	0.8 GeV/u($^{238}U^{92+}$)	$\sim10^{11\text{-}12}$ ppp

The highest intensity pulsed heavy ion beam in the world

Institute	Machine	Planned Intensity	Achieved Intensity	Ion species	Repetition rate
JINR	NICA Booster	4×10^{9}		Au^{32+}	
GSI	SIS18	1.0×10^{11}	3×10^{10}	U^{28+}	3Hz
FAIR	SIS100	4.0×10^{11}		U^{28+}	
IMP	HIAF-BRing1	2.0×10^{11}		U^{35+}	5-10Hz, 10-20Hz
IMP	HIAF-BRing2	1.0×10^{12}		U^{35+}	

HIAF Schedule



Physics Topics at HIAF

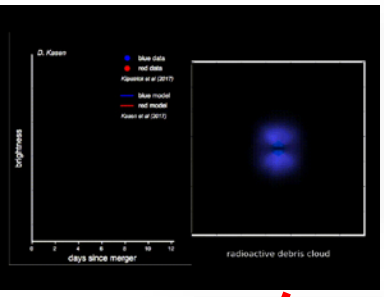
T1: Nuclear structure and reaction dynamics

T2: QCD phase structure at high baryon density

T3: QCD and Nucleon structure

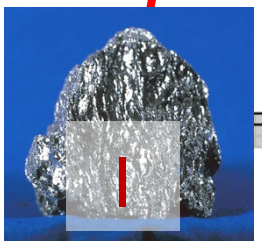
T4: Applications

T1 : The Origin of (heavy) Elements



SHE

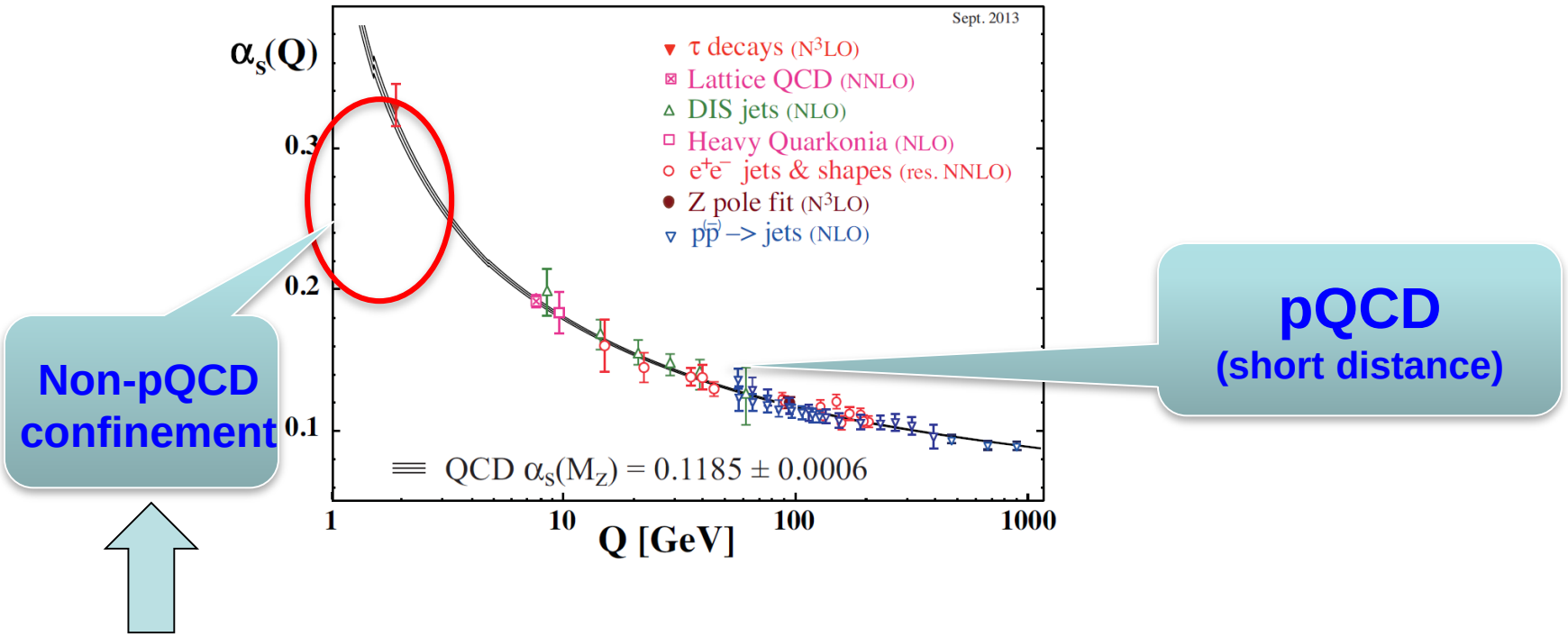
SHN Island?



- Study nuclear structure, origin of heavy elements
- To explore the limit of nuclear existence
- Provide necessary information for astrophysics

QCD phase structure and nucleon structure

- QCD is the basic theory for strong interaction
- ***QCD at short distance : is*** well defined
- ***QCD at long distance :*** little is known regarding the dynamical structures of matter, *e.g. the confinement*, ***nucleon structure***, *the* ***QCD phases structure***



CEE/HIAF: the QCD phase structure

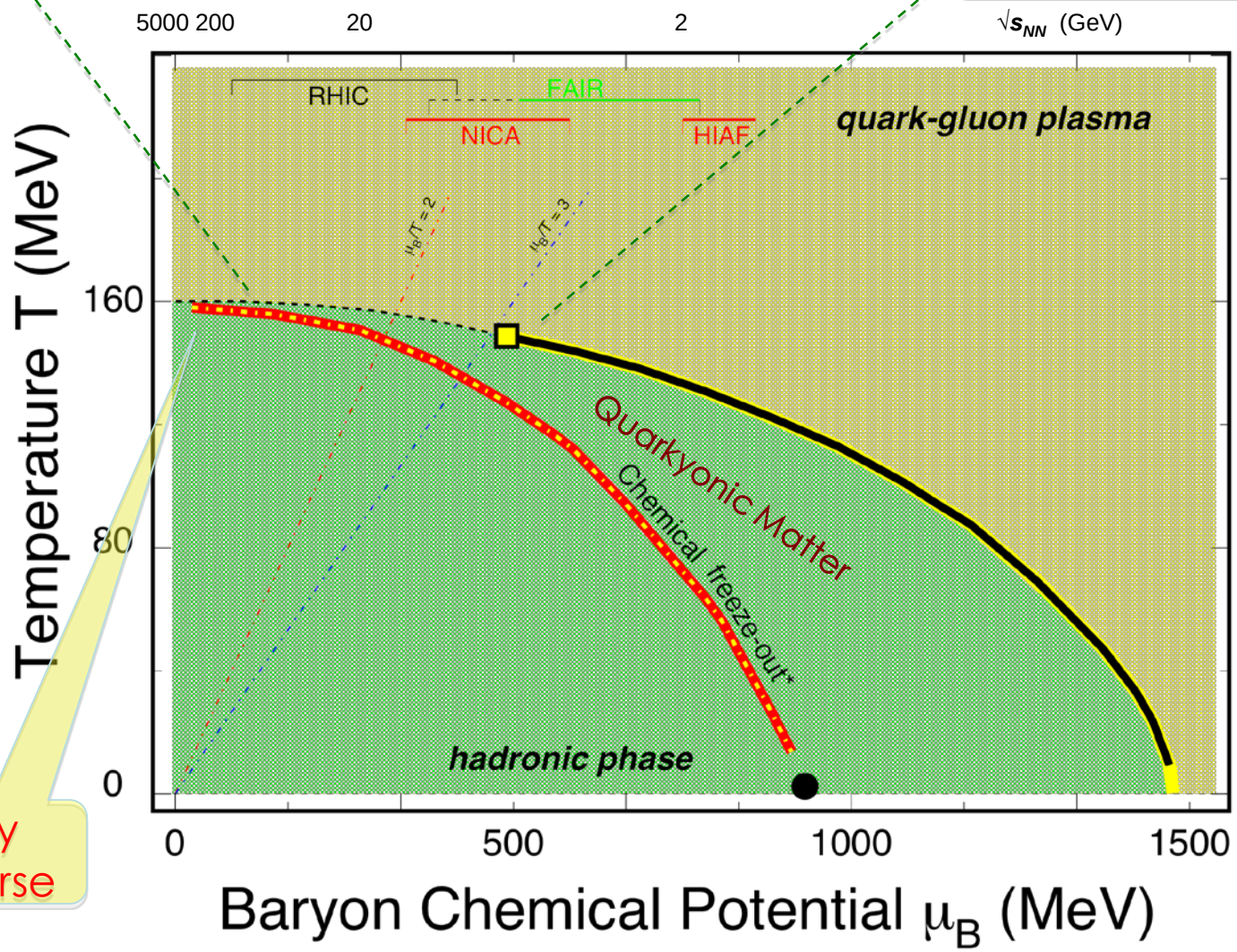
EicC: nucleon structure and hadronization

T2:QCD Phase Structure

1 T_{ini}, T_C *LHC, RHIC*

2 T_E *RHIC, SPS*

3 *CP, Large* μ_B *FAIR, NICA, HIAF*



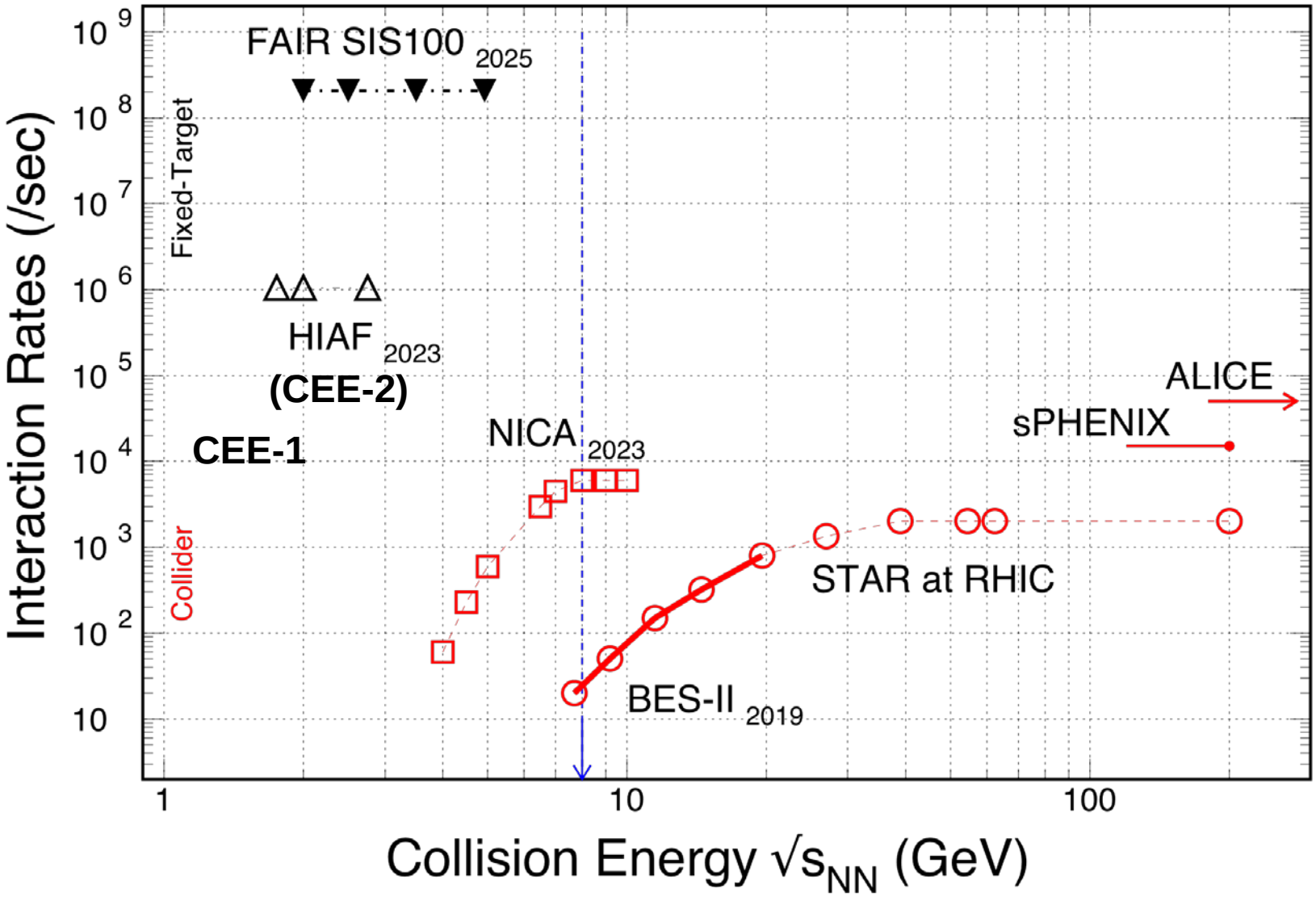
Early Universe

Neutron Stars

T_C=160 - 175 MeV ≅2*10^{12}K

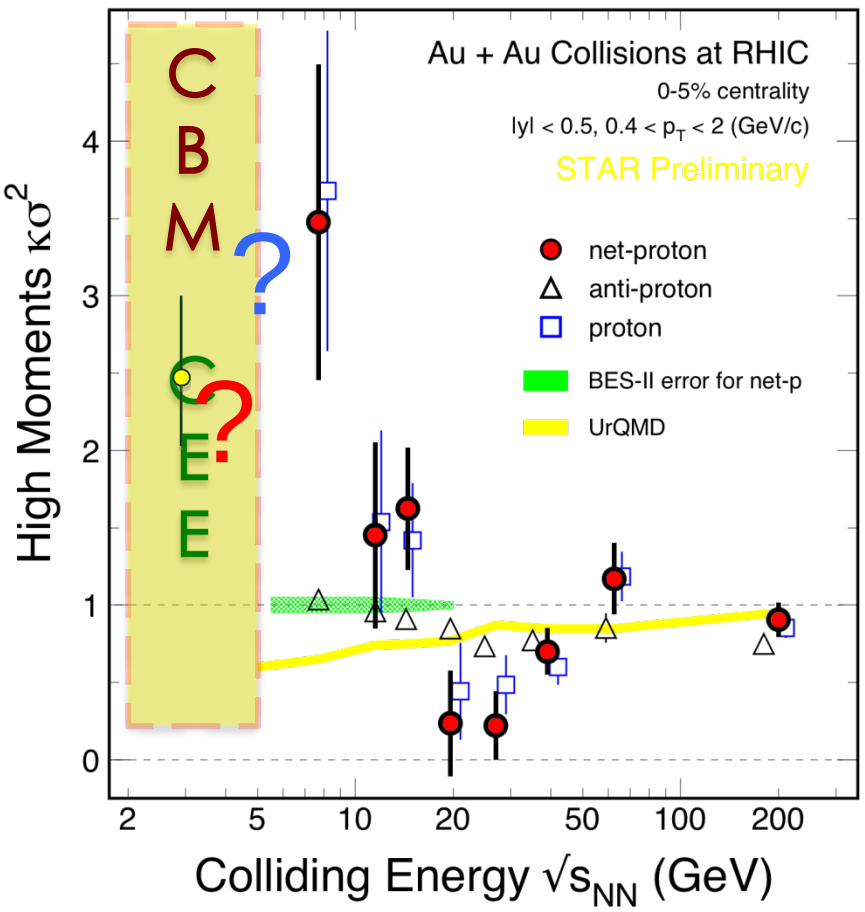
S. Gupta, X. Luo, B. Mohanty, H.G. Ritter, and N. Xu, *Science*, 332, 1525(2011)

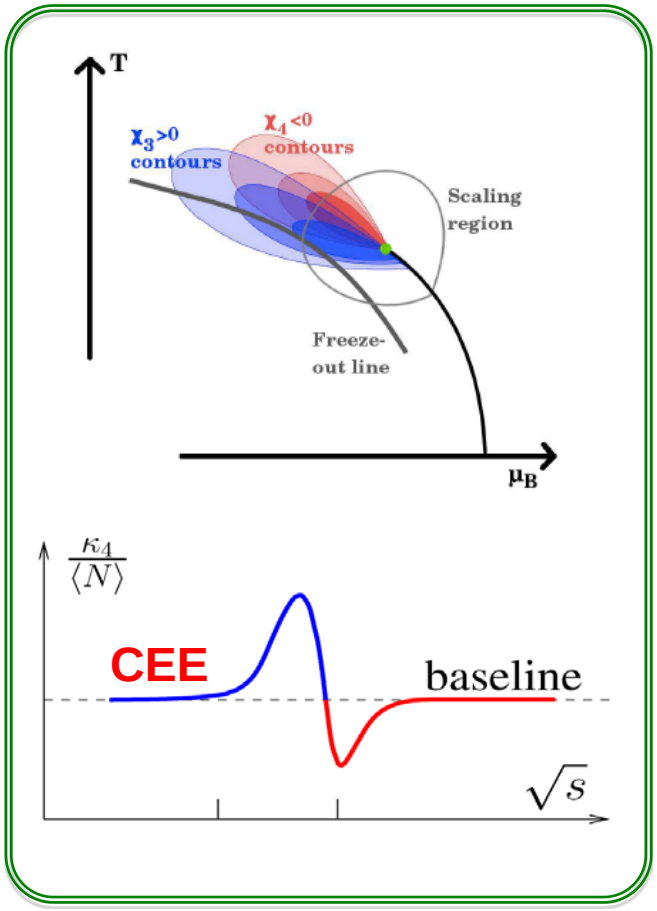
Interaction Rates for Heavy Ion Collisions



Search for the QCD Critical Point

- HADES preliminary, SQM16, |y|<0.2





- RHIC BES-II: dramatically reduce the errors!
- CBM/RHIC FXT/CEE Experiments

Key region for Critical Point search

STAR Data: X.F. Luo *et al*, CPOD2014, QM2015; PRL**112** (2014) 32302

Hunt for QCD Critical Point!

$\sqrt{s_{NN}} = 2\text{-}11\,\text{GeV}$, $800 \geqslant \mu_B \geqslant 300\,\text{MeV}$

America	RHIC	STAR (2019 - 2020)
Russia	NICA	MPD (2023)
Germany	FAIR	CBM (2025)
China	HIAF	CEE (2023)

Super Beam Energy Scan: *s*BES

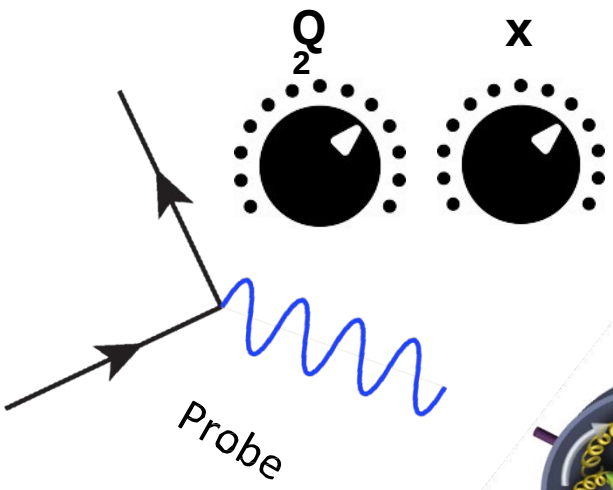
HIAF Future Plan: EicC

- **EicC-I：2028-2035**

  suggest startup R&D for EicC during 2021-2025

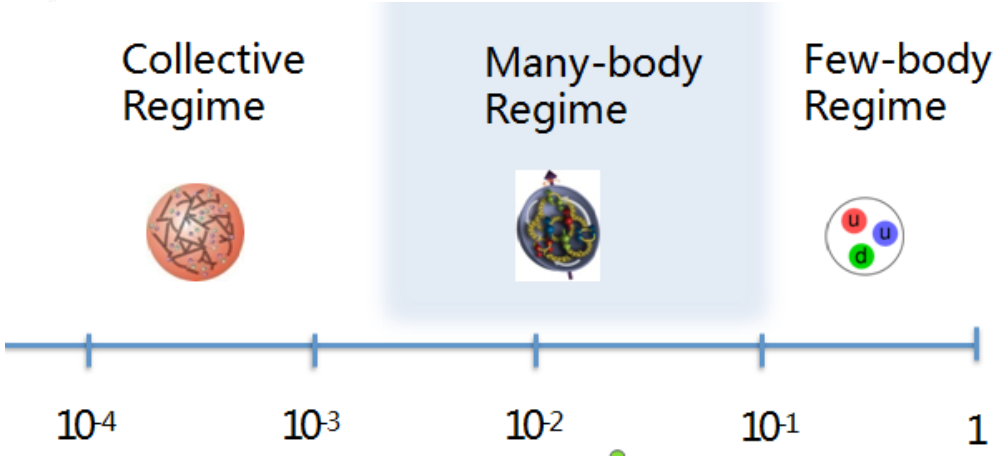
Electron-Ion Collider at China: EicC

T3: EicC: nucleon structure



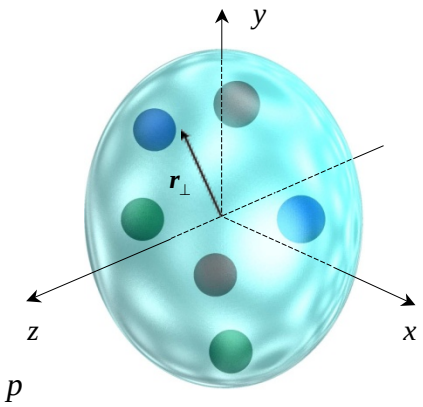
super electron microscope

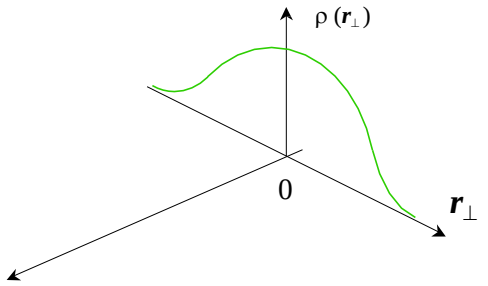
nucleon structure:
- spin of nucleon
- mass of nucleon
- role of gluons
- confinement
- exotic states
- …



EicC: the structure of the nucleon

Elastic scattering

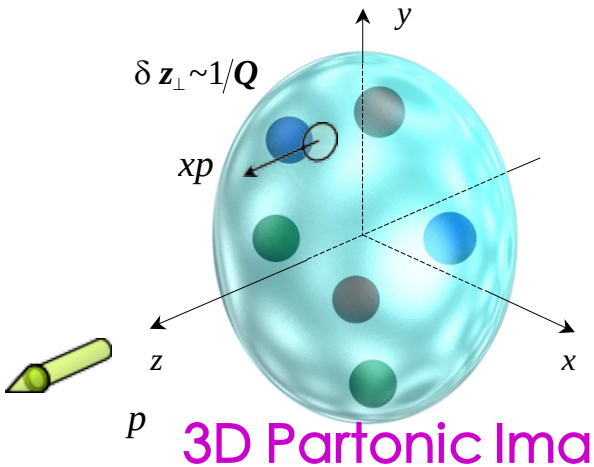


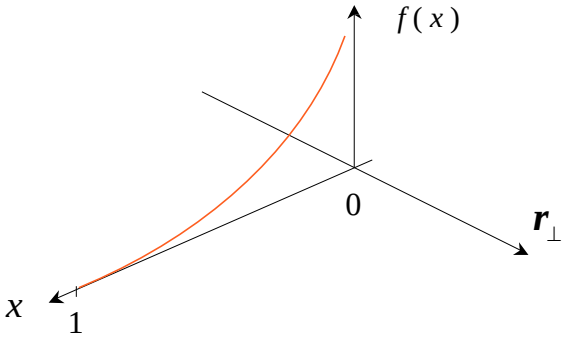


Form factors

Nobel prize, 1961

Deeply Inelastic Scattering



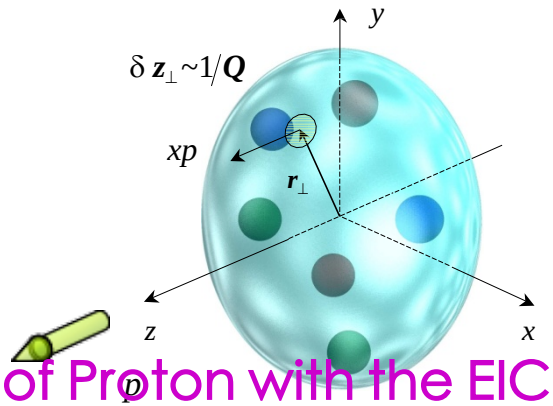


Parton distributions

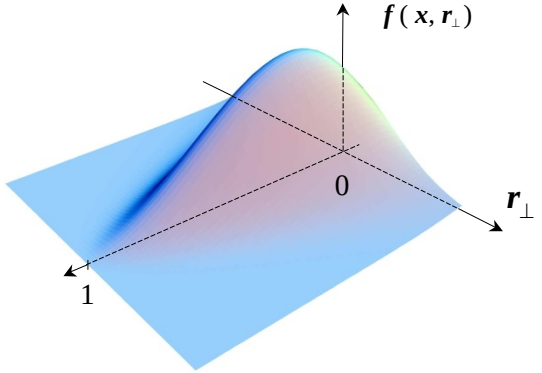
Nobel prize, 1969

Nobel prize, 1990

Hard exclusive processes



3D Partonic Image of Proton with the EIC



Generalized Parton Distributions (GPDs)

HIAF- EicC-I

Very preliminary!!

EIC-I New construction

- polarization ion source
- Siberia snake for FRing
- e injector

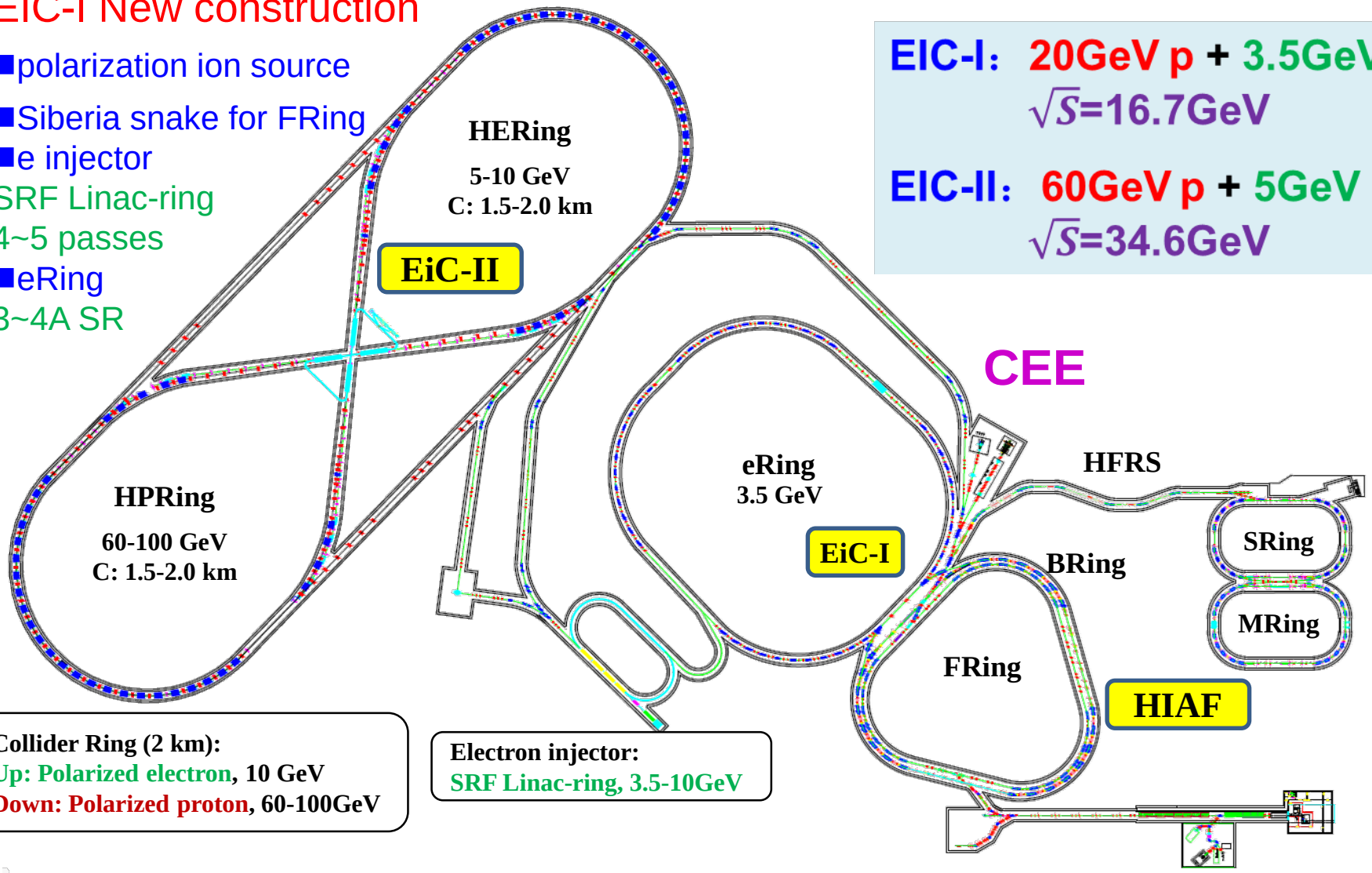
SRF Linac-ring
4~5 passes

- eRing

3~4A SR

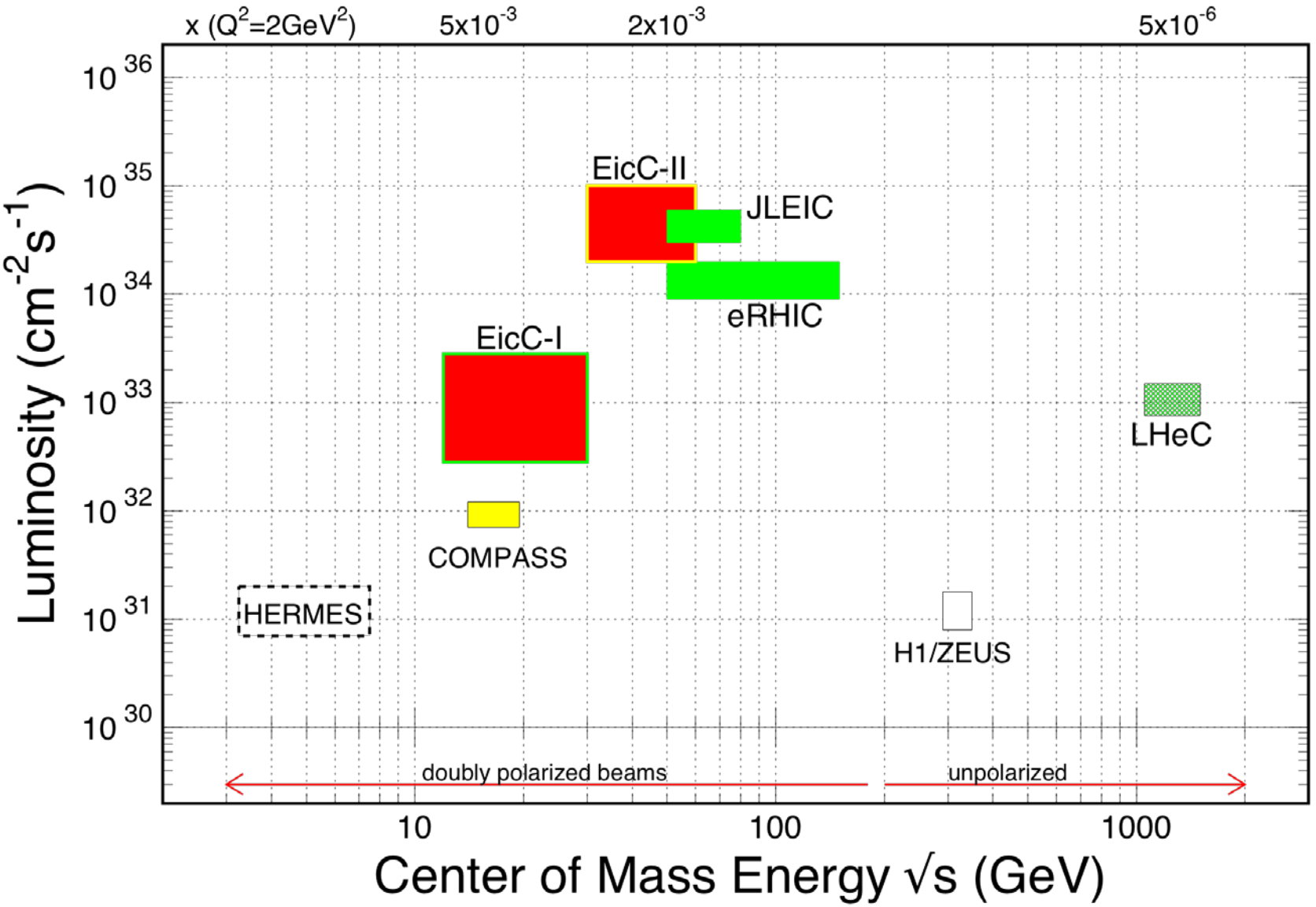
EIC-I: 20GeV p + 3.5GeV e
$\sqrt{s}$=16.7GeV

EIC-II: 60GeV p + 5GeV e
$\sqrt{s}$=34.6GeV

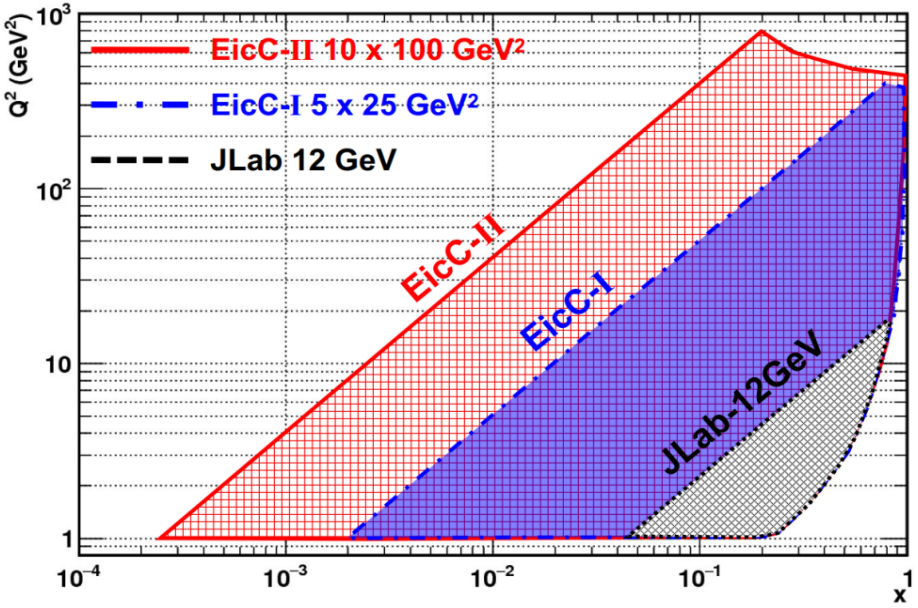


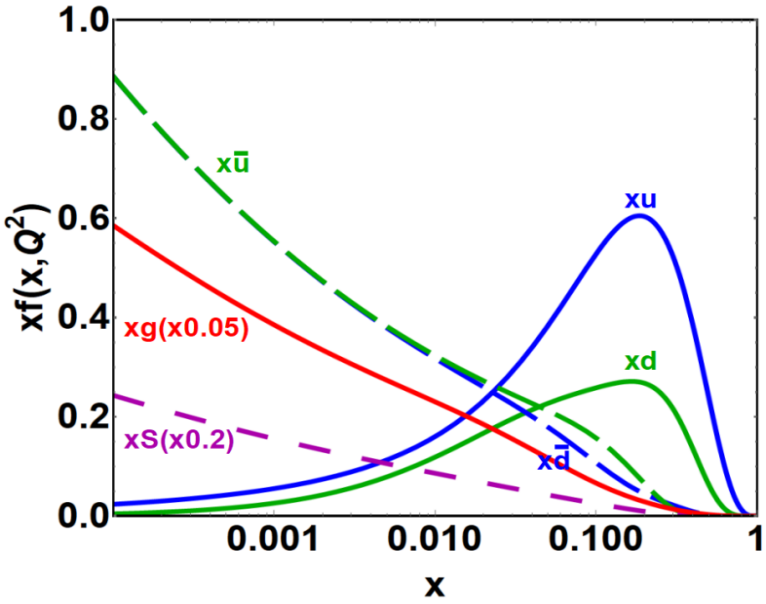
Collider Ring (2 km):
Up: Polarized electron, 10 GeV
Down: Polarized proton, 60-100GeV

Electron injector:
SRF Linac-ring, 3.5-10GeV


x (Q²=2GeV²)
5x10⁻³
2x10⁻³
5x10⁻⁶
Luminosity (cm⁻²s⁻¹)
10³⁶
10³⁵
10³⁴
10³³
10³²
10³¹
10³⁰
EicC-II
JLEIC
eRHIC
EicC-I
LHeC
COMPASS
HERMES
H1/ZEUS
doubly polarized beams
unpolarized
10
100
1000
Center of Mass Energy √s (GeV)

Machine Kinematics and Physics





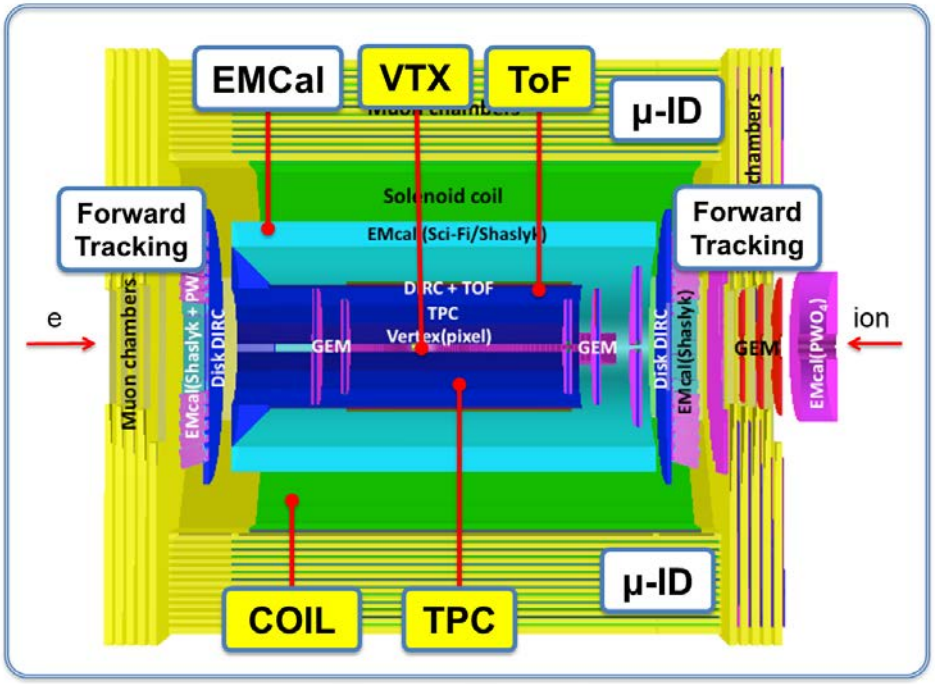
Compare the kinematic ranges of EicC with JLab 12 GeV

Facilities	Main goals
JLab 12 GeV (FXT)	Valence quark
EicC-I ($\sqrt{s}$ ~ 15 GeV)	Valence and Sea quark
EicC-II ($\sqrt{s}$ ~ 35 GeV)	Sea quark and gluon

EicC Challenge and Detector

- **Polarized electron and proton beam**
- **Interaction region or collision region design**
- **EIC detector design and construction (Forward tracking)**

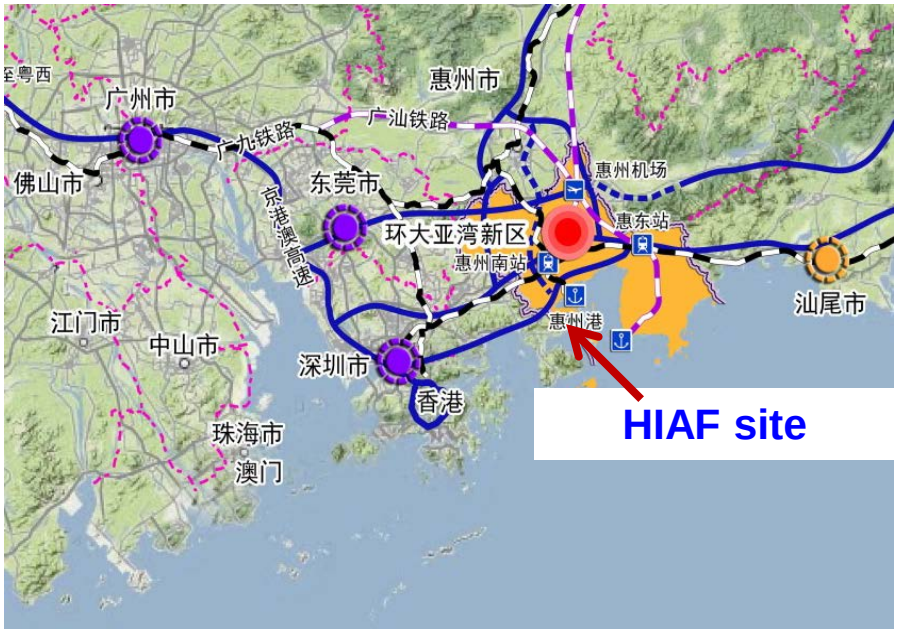
EicC Concept Detector

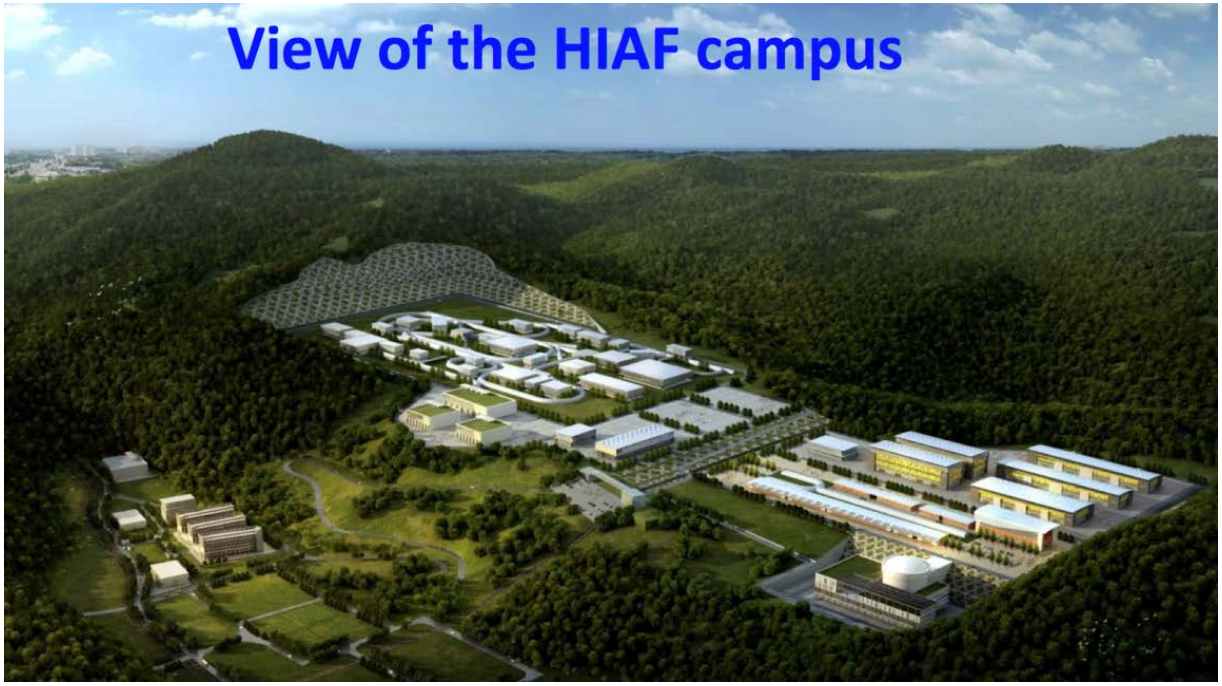


: We have the technology

: Need international collaborators

HIAF Location





Summary

- HIAF will be one of the next-generation world leading heavy ion facility for advances in nuclear physics and applications

- EicC is the future plan for high-energy nuclear physics in China
  - EicC physics programs complement the world efforts of EIC
  - the working groups are preparing for the EicC whitepaper

- HIAF and EicC: open for the domestic and international collaborations

Thank You !